Markets will set the Cost of Wind Power Integration

The cost of producing wind energy is still falling, and it is well known that the cost per kWh wind energy is now comparable with the cost of more traditional alternatives. It is less known that the relative market value of wind energy will decrease with an increased share of non-dispatchable electricity production. This effect must be considered in comparisons when the share of wind and solar energy exceeds about 20% of the electricity consumption.

A simulation of the German electricity market suggests that the market value of both wind and solar energy will be only about 55% of the market value of dispatchable energy for a 40% penetration of wind and solar energy (fig. 1).

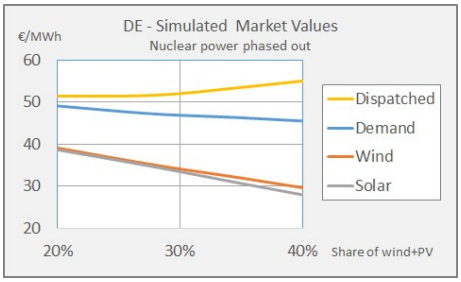

Fig. 1 – Simulated German market values

I have noticed that it can be difficult to explain the market value concept. Why can energy from different sources have different market values? This note tries to explain the market values based on a case for a single day in Western Denmark.

An ordinary day in West Danish power supply

I have selected a day without extreme conditions. On 27 November 2016, wind and solar power production was between 1000 MW and 2500 MW. The transit from Germany towards Norway and Sweden was between 0 and 1500 MW (fig. 2). The export to Norway, Sweden and Eastern Denmark was between 900 and 2700 MW.

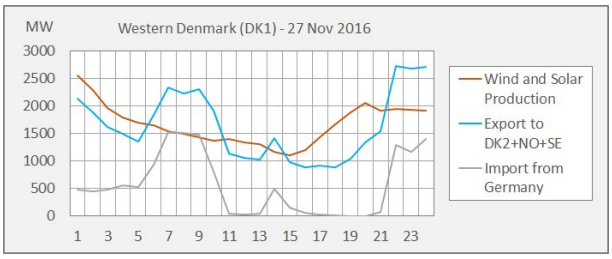

Fig. 2 – DK West is an important link in the European power grid

The exchange pattern demonstrates the important role of the Danish interconnections.

The calculation of market values will be based on prices in the Nordpool spot market (fig. 3). On 27 November 2016, the spot prices in DK1 and Germany were practically the same. It means that the prices were set in the German market. The price variation was moderate with the lowest prices in the night.

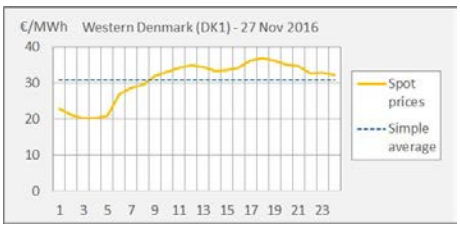

Fig. 3 - The average price: 30.77 €/MWh

The role of the Danish thermal power stations has changed. Heat for the district heating systems is the main product, while electricity is a by-product with a low marginal cost. The heat production is optimized by selling electricity in relevant markets including regulating power and primary regulation.

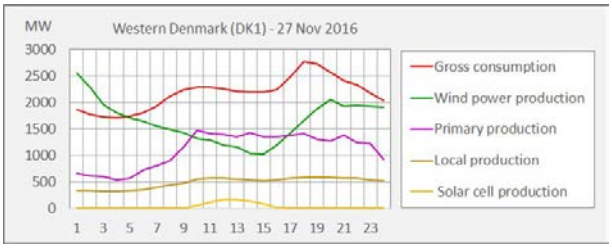

Fig. 4 - DK West: Load and production on 27 Nov 2016

The heat demand has only small variations throughout the day, but the hot water tanks on the power stations allow the electricity production to be moved to hours with high spot prices. The result is a lower electricity production in the night, when the spot prices were low (fig. 4).

The solar power is still limited in Denmark, particularly in November. The variation is predictable with a peak at noon (fig. 4).

Wind power has its own variation independent of time, electricity demand and markets.

The result is that the Danish participation in balancing Danish electricity demand and supply is very limited and the net export absorbs the variations in wind and solar power. This is not a technical necessity, but it is the optimal operation for the Danish producers (fig. 5).

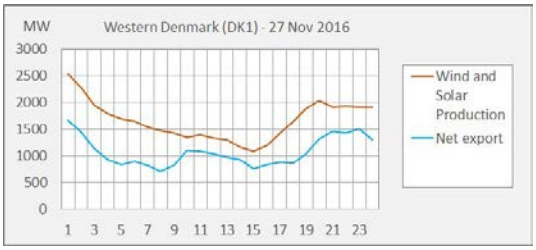

Fig. 5 – The net export follows the variations in non-dispatchable power

The figures 3 to 5 present data for the calculation of market values for one day based on hourly data, for instance for electricity consumption (load):

$$Market\ value\ of\ load = \sum_1^{24} Load(i) * SP(i) / \sum_1^{24} Load(i) = 31.44\ €/\text{MWh}$$

SP(i) is the spot price for hour number i.

The market value of the day's load is 2% higher than the simple average of the spot prices. The reason is that on that particular day hours with high load have the highest spot prices. I consider the market value of the traditional consumption to be a better reference for comparisons than the simple average of the spot prices.

DK West - Market values		
27 Nov 2016	€/MWh	Relative
Load	31,44	100,0%
Simple average	30,77	97,9%
Central CHP	32,30	102,7%
Local CHP	31,86	101,3%
Wind energy	30,15	95,9%
Solar energy	34,13	108,5%
Net export	30,61	97,4%
Wind+Solar	30,21	96,1%

Table 1 - Market value differences

Table 1 shows market values for 27 November 2016 based on spot prices. CHP means combined heat and power. It is possible to explain and understand the differences by looking at the charts. The high value of solar energy is remarkable. Solar energy combined with wind energy has a slightly higher value than the wind energy alone.

Yearly market values

All days are different. Therefore, economic results for one day are less interesting, whether the day is ordinary or extraordinary. On the other hand, the accumulated results for one year or from a sequence of years can show some stable economic differences between the electricity categories.

The results for DK West for the year 2016 (table 2) confirm that:

DK West - Market values		
2016	€/MWh	Relative
Load	27,43	100,0%
Simple average	26,67	97,2%
Central CHP	29,32	106,9%
Local CHP	29,43	107,3%
Wind energy	23,99	87,4%
Solar energy	27,39	99,8%
Net export	22,37	81,5%
Net import	28,31	103,2%

Table 2 - Market values for one year for DK West

- The value of dispatchable power (central and local CHP) is higher than the value of non-dispatchable power (wind and solar power).
- The value of load is higher than the simple average of the year's spot prices.
- The value of import is higher than the value of export.
- The value of solar power is higher than the value of wind power.

Denmark has two price zones in the Nordpool spot market. Table 3 shows the market values for the whole country. The simple average of spot prices makes no sense for two price zones of different sizes. This is another reason for using the market value of the load as a reference.

The price level is slightly higher for DK East. It affects the market values for the whole country, but the essential relations are the same as listed above.

DK - Market values		
2016	€/MWh	Relative
Load	28,65	100,0%
Central CHP	30,00	104,7%
Local CHP	30,18	105,3%
Wind energy	24,55	85,7%
Solar energy	28,47	99,3%
Net export	20,04	69,9%
Net import	30,70	107,2%

Table 3 – Market values for one year for Denmark

The impact of wind power

It is a common understanding that Danish wind power overflow is sold for nothing to the neighbouring countries, while Denmark must import during calm periods at exorbitant prices. The market values in table 3 show that this view is exaggerated.

However, there is an increasing gap between export and import prices (fig. 6). The reason for the gap is the increasing share of non-dispatchable electricity production, particularly in Germany.

There is a certain correlation between German wind power and the spot prices. High spot prices follow low wind power output and vice versa. Therefore, the average market value of wind energy is lower than the value of energy from dispatchable power stations.

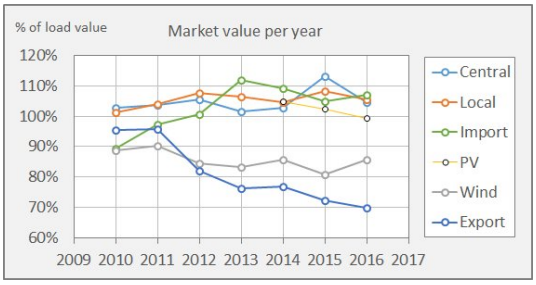

Fig. 6 - Market values Denmark 2010-2016

The non-dispatchable generation creates hours with surplus of power and low spot prices and other hours with deficit of power and high prices. The *price volatility* has increased.

The implementation of smart grids with flexible electricity demands has been discussed for at least 20 years, but very little has happened so far.

The value of wind energy in Denmark seems to have stabilized at about 80% of the value of energy from dispatchable sources. The difference can be seen as a cost of integrating wind power and must be considered in comparisons with alternative production methods.

It is difficult to predict if the wind power value in Denmark will remain stable at the present level. The future spot price volatility in Germany will be decisive. Therefore, there is good reason for a close observation of the German *Energiewende* during the next few years.